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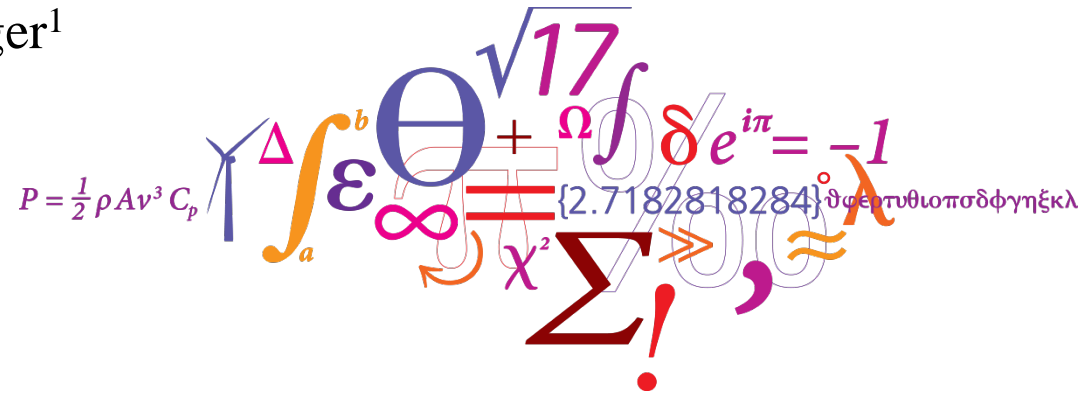
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Offshore Extreme Wind Atlas Using Wind-Wave Coupled Modeling

Xiaoli Guo Larsén¹, Jianting Du¹, Rodolfo Bolanos²,
Marc Imberger¹ and Merete Badger¹

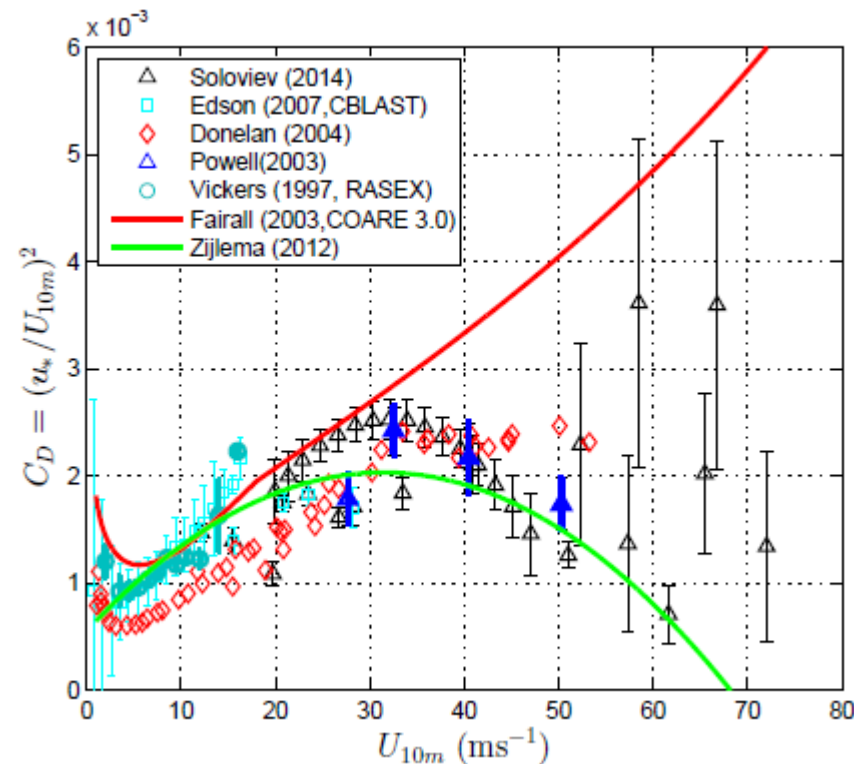
1. DTU; 2. DHI



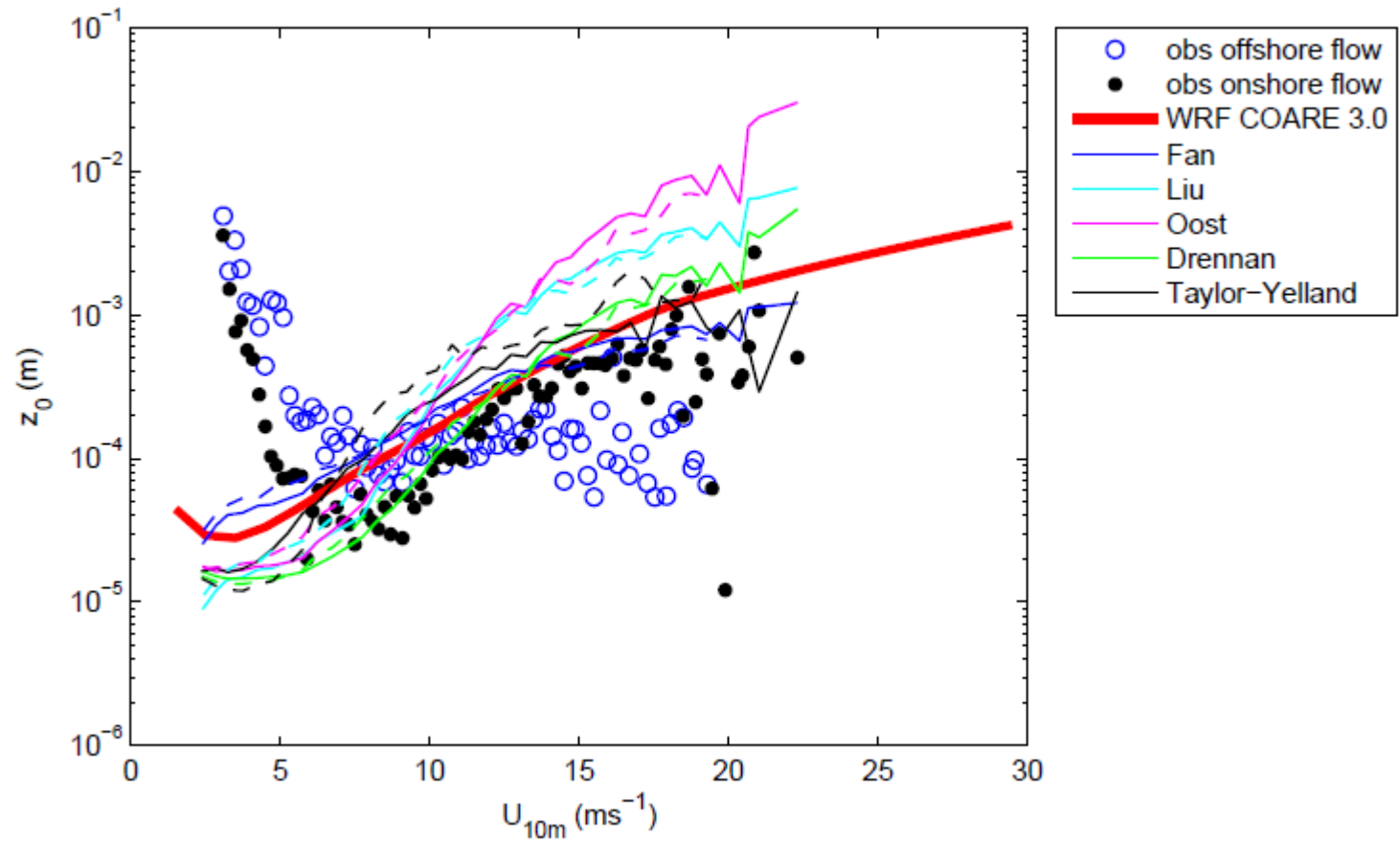
Relevance of the study/state-of-the-art



Relevance of the study/state-of-the-art



Relevance of the study/state-of-the-art



Method for obtaining the 50-year wind

1. Collecting the samples:

Selective Dynamical Downscaling Method – Storm Episodes

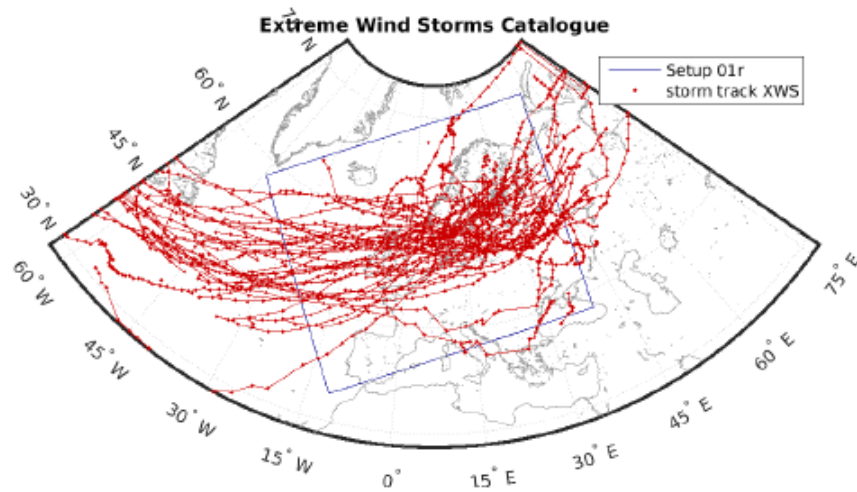
1994	19940104	19940122 19940123 19940124	19940128	19940131	19940313 19940314	19940324	19940623	19940909	19940915 19940916	19940927	19941123	19941208					
1995	19950110	19950120	19950122 19950123	19950127	19950131	19950201	19950204 19950205 19950206	19950212	19950220	19950222 19950223	19950228	19950327	19950407 19950408	19950915	19950926	19950928	19951018
1996	19960210	19960216	19960218 19960219 19960220	19960228 19960229	19960709	19960912	19961027	19961029 19961030	19961105 19961106 19961107	19961205	19961214						
1997	19970114	19970130	19970204	19970208	19970211	19970214	19970217 19970218 19970219 19970220 19970221 19970222	19970225	19970301 19970302 19970303	19970326 19970327	19970410 19970411	19970414	19970630	19970908 19970909	19971002	19971005	19971010 19971011
1998	19980105	19980119	19980223	19980227	19980304 19980305	19980311	19980326	19980403	19981023 19981024 19981025 19981026 19981027 19981028	19981109	19981205	19981213	19981226				
1999	19990125	19990204 19990205	19990303	19991129 19991130	19991201	19991203 19991204	19991217										
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2011																	
2012	20120104 20120105					20150111										20121214	
2013	20130131					20160128				20160208							
2014	20140106	2016	20160108			20160129	20160202			20160209	20160221	20160222	2016	20140809 20140810	20140922	20140926	
2015	20150102					20160130				20160210							
2016	20160108																

1994 – 2016, 429 stormy days

5%

Method for obtaining the 50-year wind

2. Modeling the samples:



Optimization of model setup

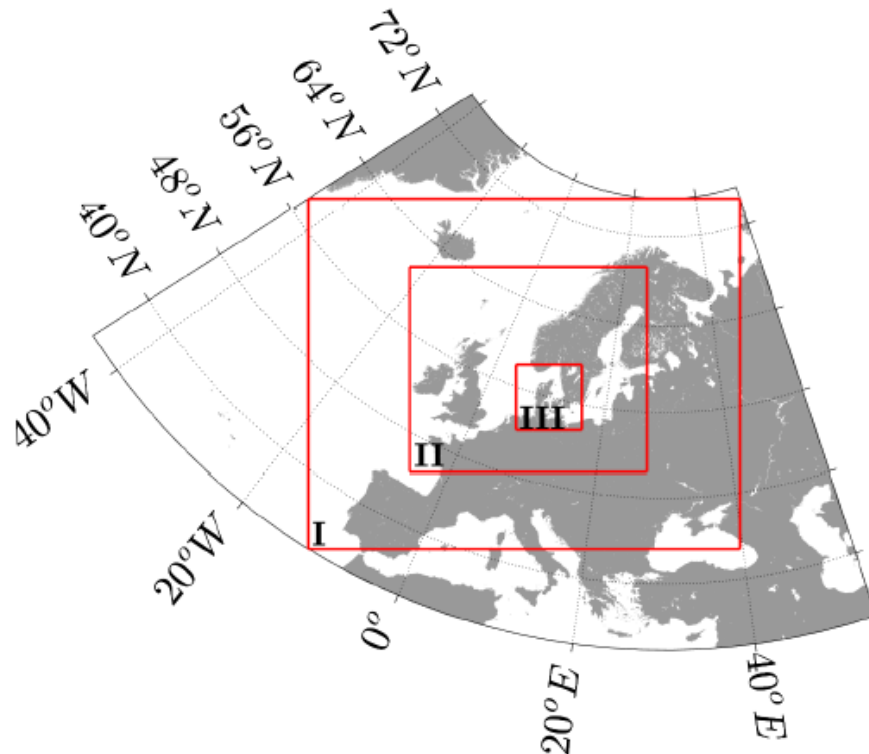
With consideration of:

- 1) Domain size
- 2) Domain location
- 3) Initial time
- 4) Simulation length
- 5) Spinning up time
- 6) Resolution

Imberger M. 2017: Modeling rough weather over the North Sea – using COWAST for offshore wind energy applications. DTU Wind Energy-M-0149, Master thesis.

Method for obtaining the 50-year wind

2. Modeling the samples:



Two-way online
Nested 18-6-2km
36 hours for each run

WRF:
CFSR+OISST
77 vertical sigma levels
MYNN 3.0 PBL scheme
RRTM long and short wave radiation
Kain-Fritsch cumulus scheme (domain I)
Corine land use

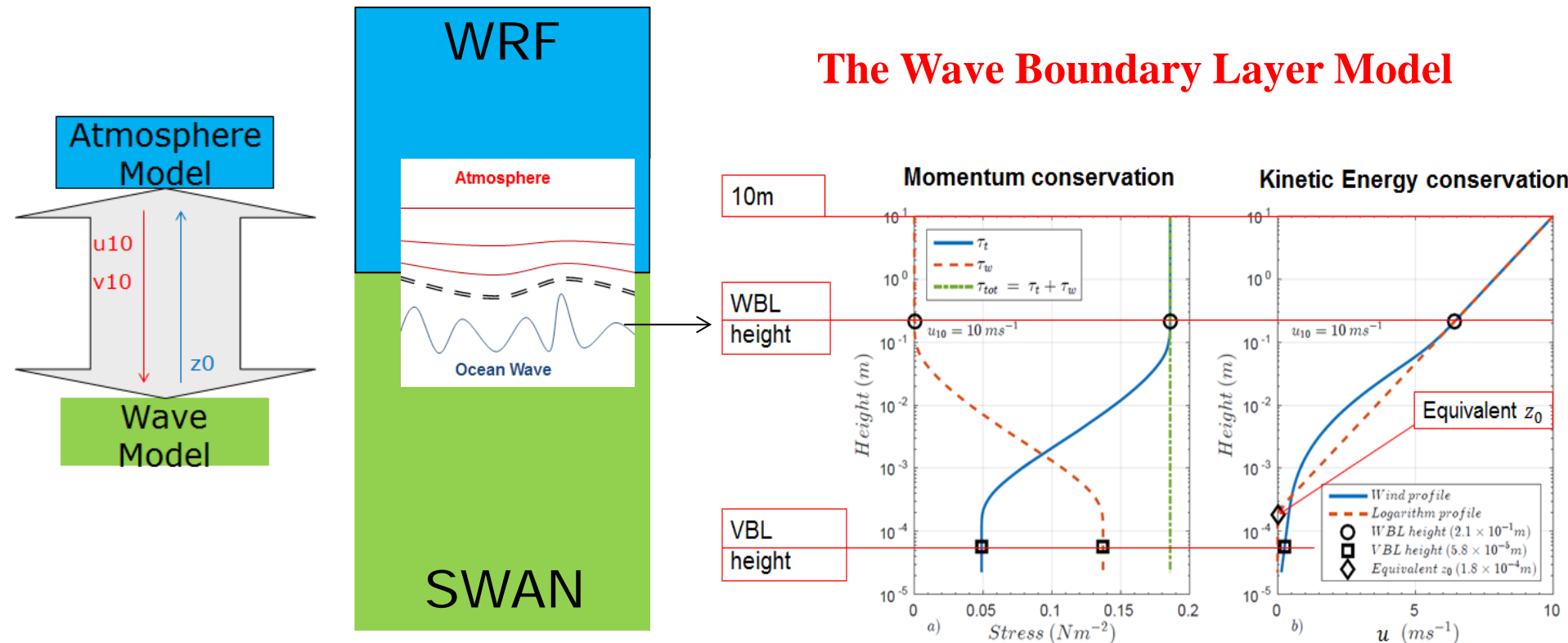
WBLM

SWAN:
1/8 arc-minute bathymetry data
Initiated 24h before the simulation
Close boundary for open sea
36 directional bins.
 $0.03 \text{ Hz} < f < 10.05 \text{ Hz}$ (KOM and WBLM)
 $0.03 \text{ Hz} < f < 0.57 \text{ Hz}$ (JANS)

Method for obtaining the 50-year wind

2. Modeling the samples: the WBLM

The Wave Boundary Layer Model

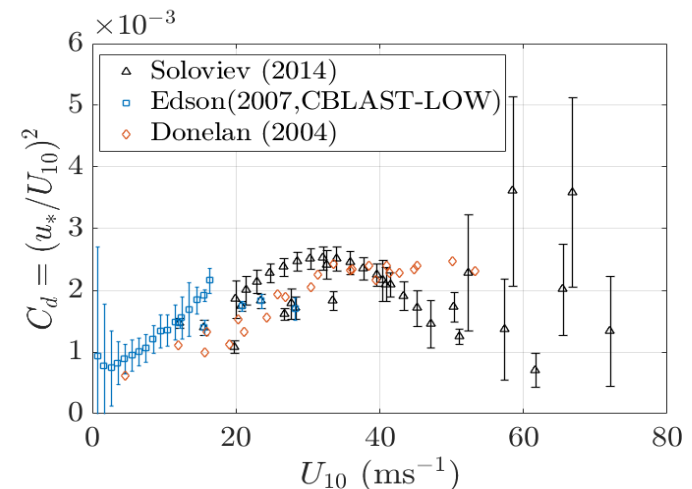
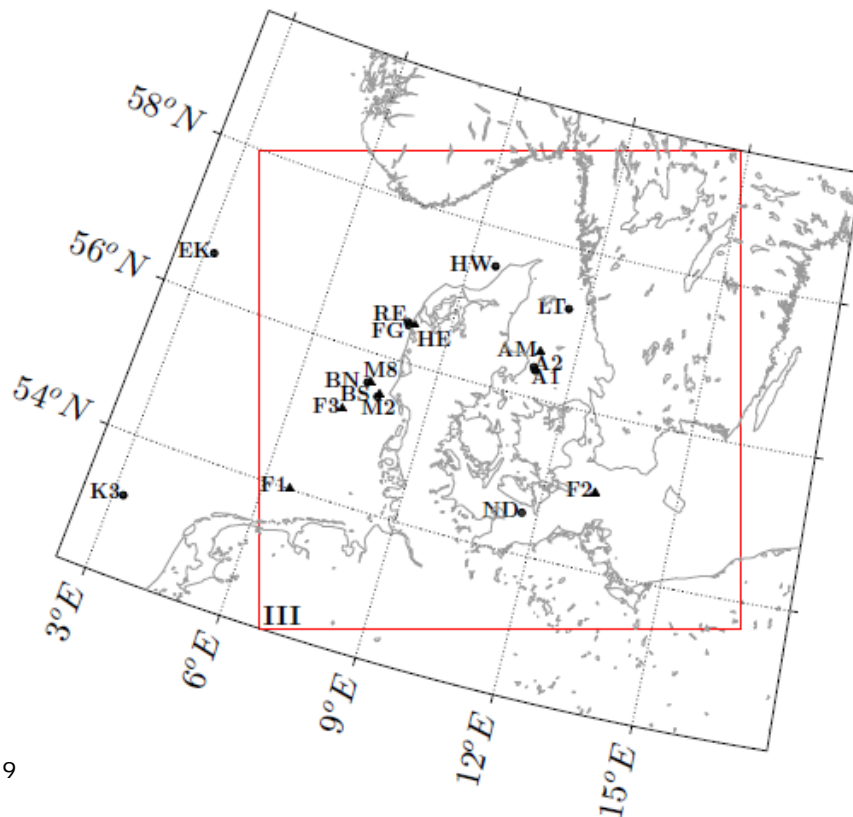


Du, J., Bolaños, R., and Larsén, X. (2017a). The use of a wave boundary layer model in SWAN. *Journal of Geophysical Research: Oceans*, pages 1063–1084.

Method for obtaining the 50-year wind

3. Validation of the modeling: general validation

- Point measurements (mast, buoy, lidar)
- Satellite data (SAR, Quikscat, cloud images)
- The literature



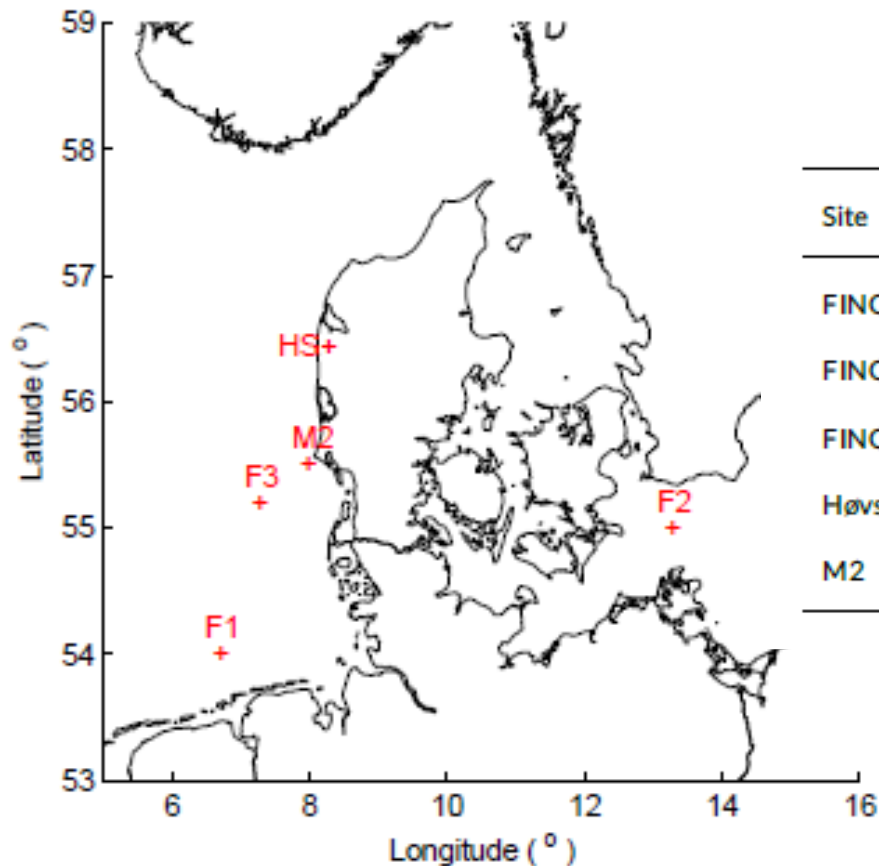
Soloviev (2014): A collection of measurements from Powell (2003), Black (2007, CBLAST-Hurricane), Bell (2012), Jarosz (2007), Holthuijsen (2012)

Edson (2007): CBLAST-LOW

Donelan (2004): Laboratory measurements in a wave tank (15m long x 1m wide x 1m high)

Method for obtaining the 50-year wind

3. Validation of the modeling: U50

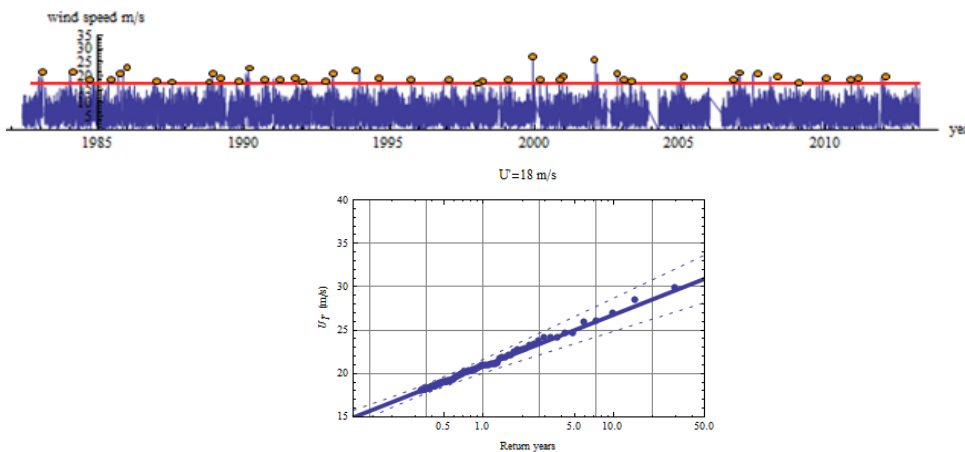


Site	Coordinates	Period	Data length (years)	Height (m)
FINO1	6.588°E, 54.014°N	2004 - 2017	14	100
FINO2	13.1542°E, 55.007°N	2008 - 2017	10	102
FINO3	7.1583°E, 55.195°N	2010 - 2017	8	100
Høvsøre	8.15°E, 56.433°N	2005 - 2017	13	100
M2	7.875°E, 55.508°N	2000 - 2005	6	62

Method for obtaining the 50-year wind

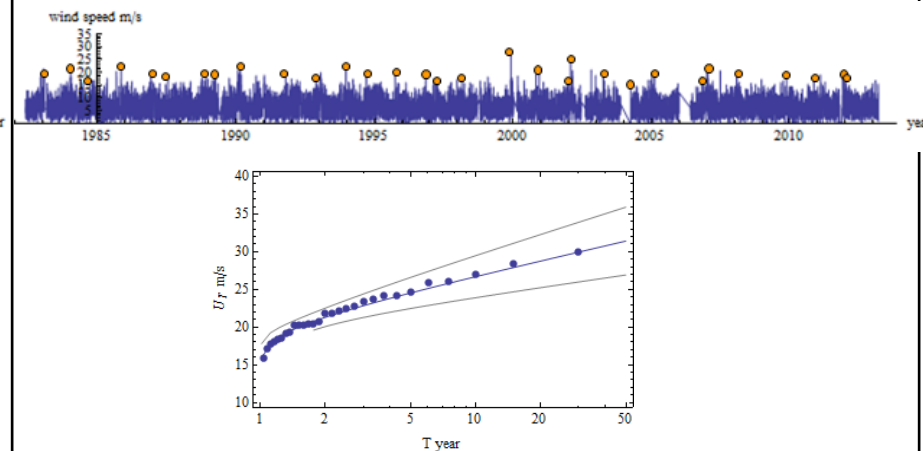
2. For calculating the 50-year return value

Peak-Over-Threshold Method



$$U_T = u_0 + A \ln(\lambda T)$$

Annual Maximum Method



$$U_T = \alpha^{-1} \ln(T/T_{BP}) + \beta$$

Applied to measurements only

to both measurements and modelled data

Questions:

Have we captured the relevant storms?

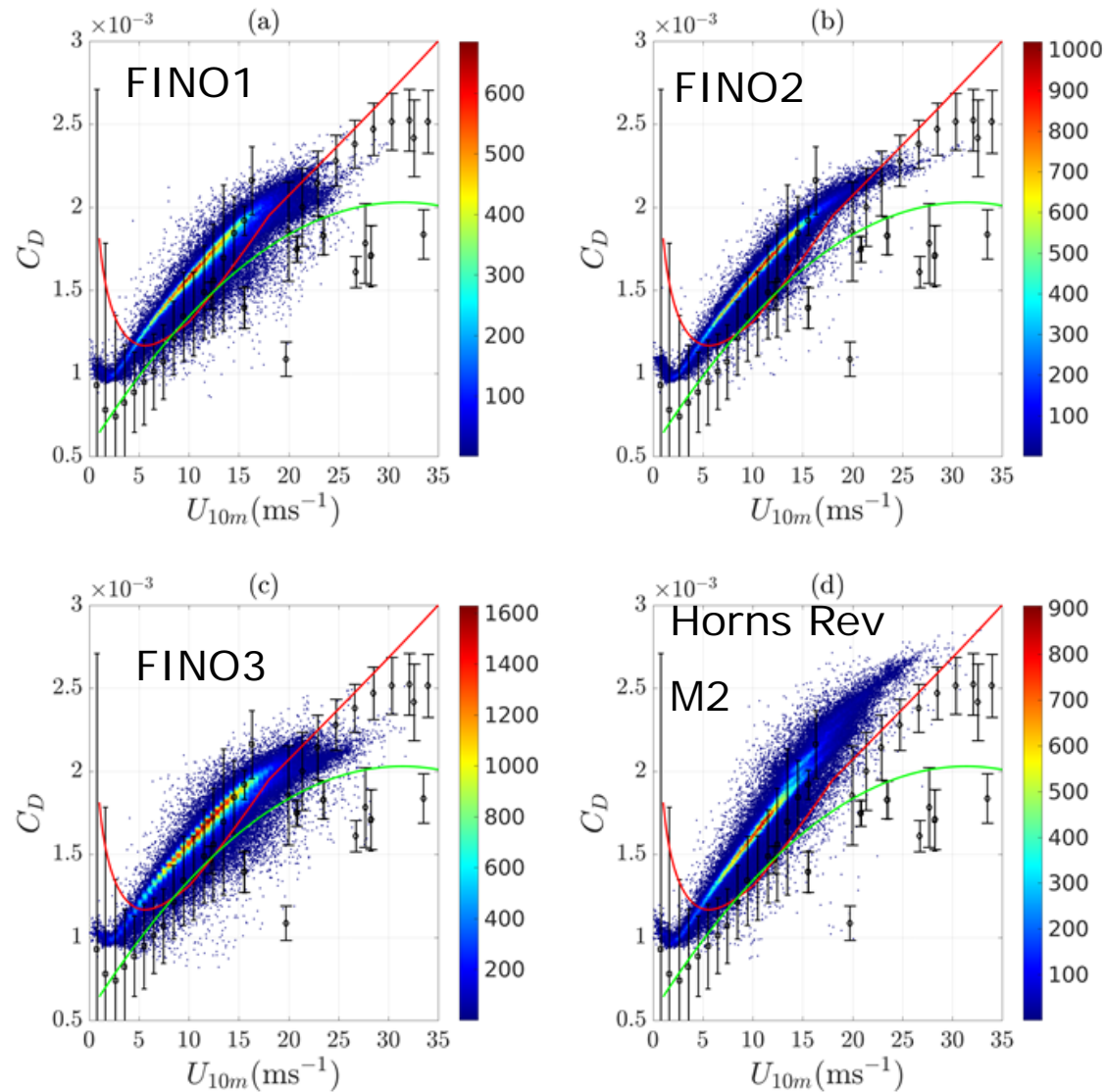
How is the general model performance?

How is the estimate of U50, coupled vs not-coupled?

Results

Question 2:
How is the general model performance?

Results



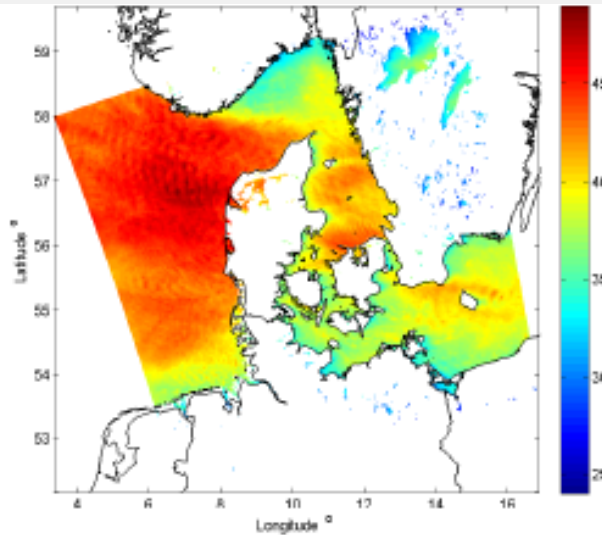
Results

Question 3:

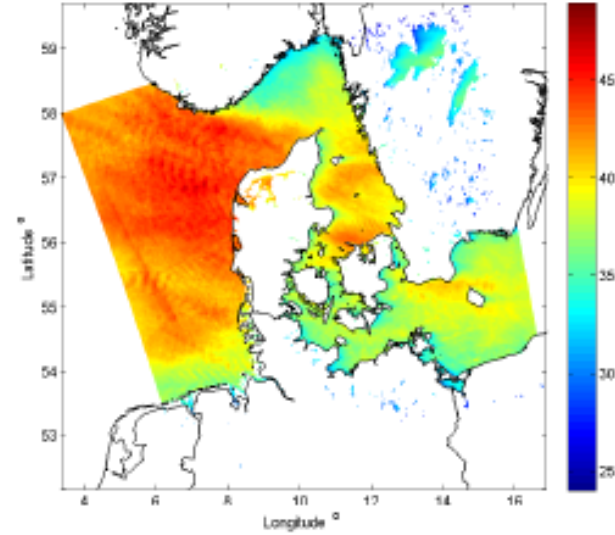
How is the estimate of U_{50} ?

Results

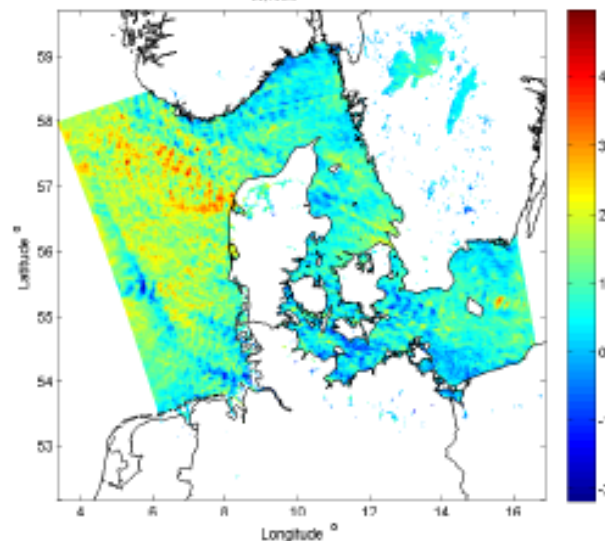
(a) U50 at 100 m, coupled



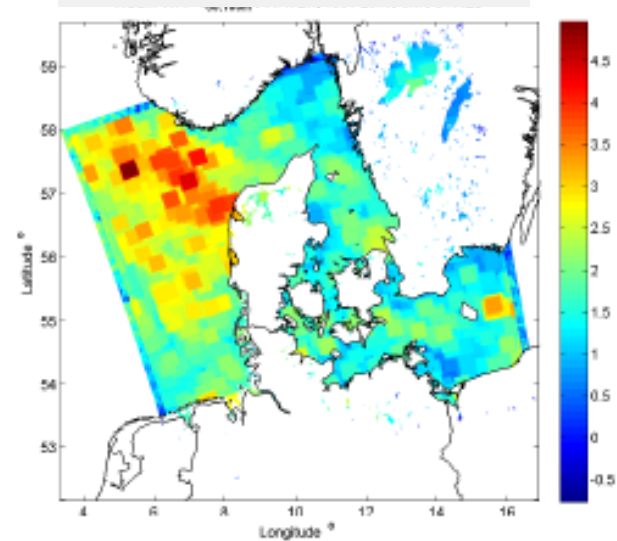
(b) U50 at 100 m, not-coupled



(a) – (b)



(a) – (b), smoothed



Results

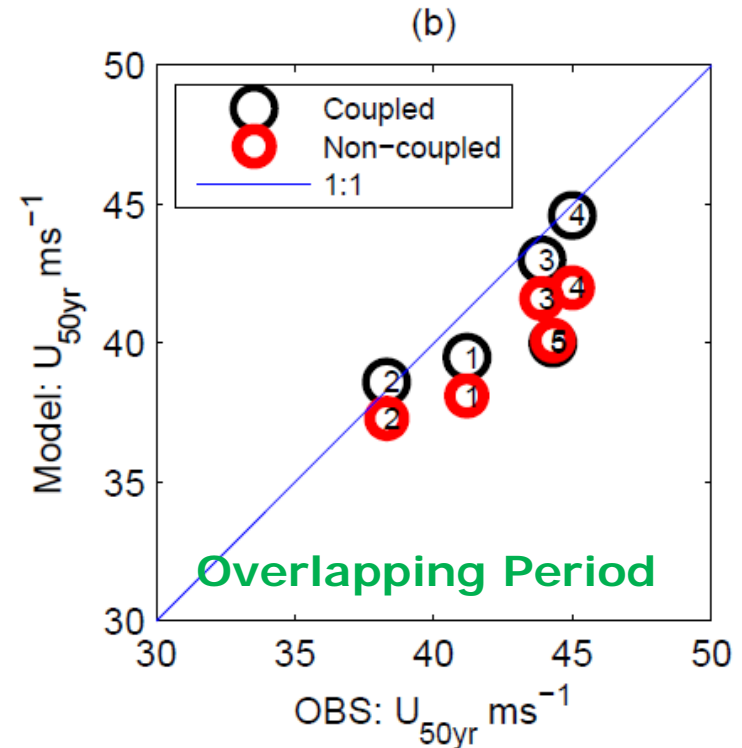
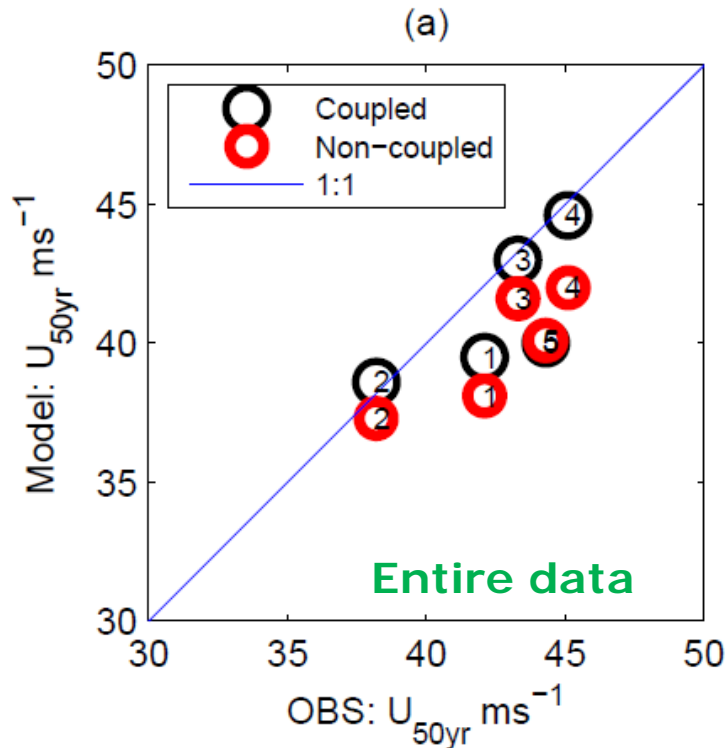


Table 1 – Basic parameters for wind turbine classes²

Wind turbine class	I	II	III	S
V_{ref} (m/s)	50	42,5	37,5	Values specified by the designer
A I_{ref} (-)	0,16			
B I_{ref} (-)	0,14			
C I_{ref} (-)	0,12			

- 1: FINO 1
- 2: FINO 2
- 3: FINO 3
- 4: Høvsøre
- 5: Horns Rev M2

Summary

- Selective dynamical downscaling method is efficient and reliable
- The WRF-WBLM-SWAN model improves strong wind calculation in comparison with WRF-alone

Acknowledgement

The Danish ForskEL project X-WIWA (www.xwiwa.dk)

The EU CEASELESS project

Sub materials

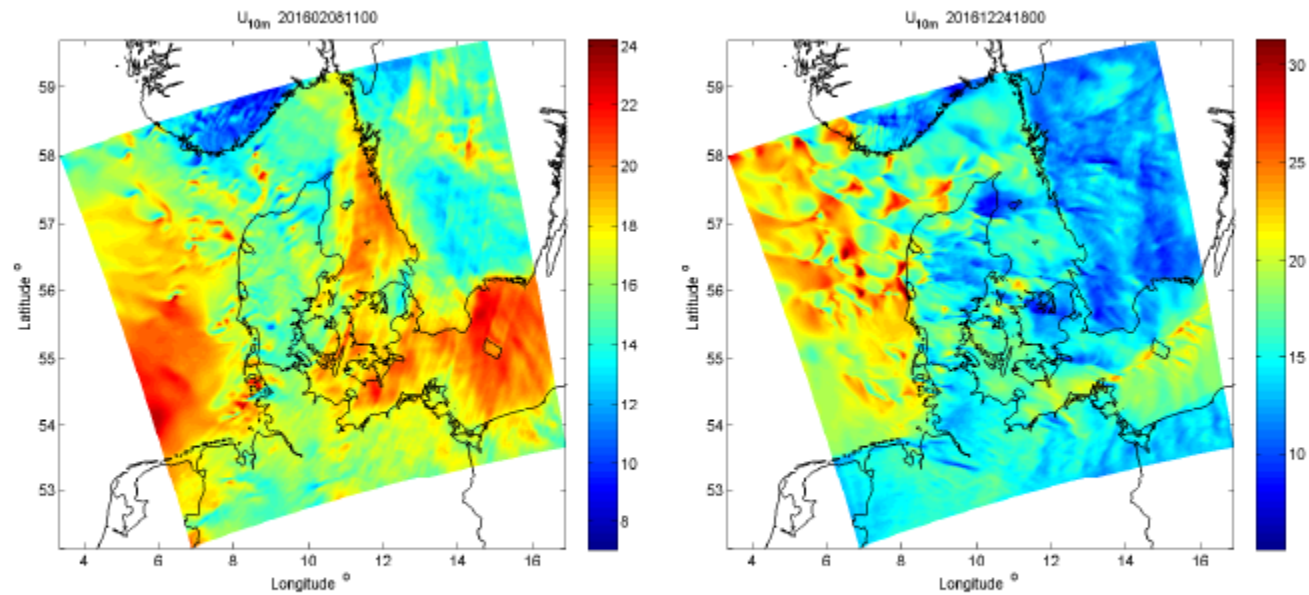


FIGURE 8 Examples of the wind fields in the presence of open cells: 2016-02-08 11:00 and 2016-12-24 18:00.